Microstructure and plasticity from nanoscale to macroscale

Hansen, Niels; Zhang, Xiaodan; Huang, Xiaoxu

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Microstructure and plasticity from nanoscale to macroscale

Niels Hansen, Xiaodan Zhang, Xiaoxu Huang

Danish-Chinese Center for Nanometals, Materials Science and Advanced Characterization Section, Department of Wind Energy, Ris1ø Campus, Technical University of Denmark, DK-4000 Roskilde, Denmark

Microstructure and plasticity are investigated in the surface/subsurface layer of a low alloy steel plastically deformed by particle bombardment (shot peening). The microstructure of the surface/subsurface layer is graded on a length scale from nanometer to micrometer and it extends to about 600 μm below the surface. Based on a quantification of microstructural parameters the flow stress has been analyzed based on three major strengthening mechanisms: (i) dislocation (forest) strengthening, (ii) boundary (Hall-Petch) strengthening and (iii) solid solution hardening. Based on additivity of strength contributions the flow stress gradient in the surface/subsurface layer is calculated and compared with hardness profiles determined by micro and nanoindentation techniques. Good agreement is found showing that the flow stress at the surface is about 1400 MPa and in a depth of 25 and 600 μm, 800 MPa and 300 MPa respectively. Based on this analysis a contribution to the flow stress from macro and micro residual stresses is discussed with reference to residual stress measurements by X-ray diffraction (XRD) techniques. Finally the combination of a microstructural analysis and hardness measurements on the micro and nanometer scale is discussed with a view on the local stress and strain distribution in non-homogeneous deformation structures, e.g., at surfaces, grain boundaries, coarse particles and cracks.

Reference:

[1] Hall–Petch and dislocation strengthening in graded nanostructured steel. Xiaodan Zhang, Niels Hansen, Yukui Gao, Xiaoxu Huang. Acta Materialia 2012; 60: 5933-5943.